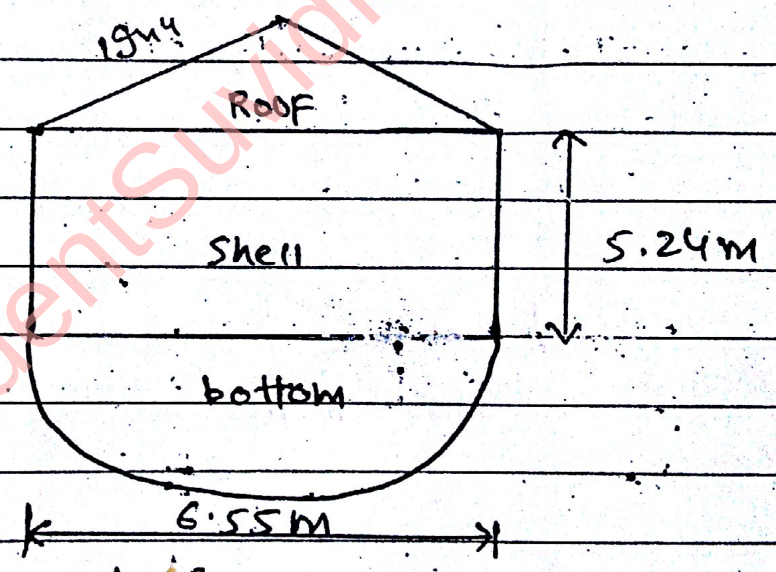
CIRCULAR TANK

Q1 Design a elevated circular water Tank for a capacity of 2,50,000 litres. The height of the Tank bottom above the ground level is 8.7m. The tank is supported over 8 columns and is situated at Railway station in Allahbad.

Sol.



Cylindrical Tank

(I) [Size of tank] :-

Capacity of Tank = 2,50,000 l

= 250 m^3

Assume hemispherical bottom of the Tank with Conical Roof (most common)

Assume height of cylindrical shell to be 0.8 times the Diameter of the Tank or $\left[\frac{H}{D} = 0.8\right]$ ← Fix

Now, Area.[Height] = Volume
And vol. = $250 m^3$
[vol. of cylinder + vol. of hemisphere = $250 m^3$]

$$\pi r^2 H + \frac{1}{2} \times \frac{4}{3} \pi r^3 = 250$$

$$\frac{\pi}{4} D^2 H + \frac{1}{2} \times \frac{4}{3} \pi \left(\frac{D}{2}\right)^3 = 250$$

or, $$\frac{\pi}{4} D^2 (0.8D) + \frac{1}{2} \times \frac{4}{3} \pi \left(\frac{D}{2}\right)^3 = 250$$

$$[D = 6.55 m]$$

Hence, $H = 0.8 D = 0.8 (6.55)$

$$\therefore [H = 5.24 m]$$

(II) [Thickness of Plates] :-

Assume the effeceincy of Joints to be 75% and let us provide 16 mm power driven Rivets for making Connections.

→ Thickness of shell Plates :-

$$\left[t = \frac{wHD}{\ldots} \right]$$

$$t = \frac{\overbrace{9.81\times10^{-6}}^{w} \times \overbrace{5.24\times10^{3}}^{H} \times \overbrace{6.55\times10^{3}}^{D}}{2\,(0.75)\,(\underbrace{120}_{\sigma_{at}})}$$

[$t = 1.87$ mm]

Here, w = unit wt. of water

i.e $9.81\ kN/m^3$ or $9.81\times10^{-6}\ N/mm^3$

Add 1.5 mm extra to account for Corrosion

$t = 1.87 + 1.5 = \underline{3.37\ mm} < 6\ mm$

∴ provide 6 mm thick plates in the cylindrical shell of the Tank.

→ <u>Thickness of Suspended bottom plates :-</u>

$$\left[t = \frac{w h D}{4 \eta \sigma_{at}} \right], \left\{ h = H + \frac{D}{2} \right.$$

$h = 5.24 + \frac{6.55}{2} = \underline{8.515\ m}$

$$t = \frac{9.81\times10^{-6} \times 8.515\times10^{3} \times 6.55\times10^{3}}{4\times0.75\times120}$$

[$t = 1.52$ mm]

Add 1.5 mm extra for corrosion

$t = 1.52 + 1.5 = \underline{3.02\ mm} < \underline{6\ mm}$

∴ Provide 6 mm thick plates in hemispherical bottom of tank.

=

Conical Roof :-

Provide 5 mm thick plates for the Conical Roof. The pitch of the Roof may be kept 1 in 4.

(III) [Connections] :-

Provide 16 mm power Driven Rivets and double Riveted lap joints have been used all through.

→ cylindrical shell plates :-

Hoop stress per linear vertical height

$$\left[F_1 = \frac{wHD}{2}\right]$$

$$= \frac{9.81\times10^{-6}\times 5.24\times10^{3}\times 6.55\times10^{3}}{2}$$

$F_1 = [168.35\ N/mm]$

Since Nominal Dia. = 16 mm

Gross Dia. = 16 + 1.5 = 17.5 mm

Strength of Rivets in single shear :-

$$= \frac{\pi}{4}\times(17.5)^2\times\frac{(0.8\times 90)}{(\tau_{vf})}$$

$$= 17318.03\ N \qquad \left[0.8\,\frac{\pi d^2}{4}\cdot\frac{\tau_{vf}}{1}\right]$$

Strength of Rivet in Bearing :-

$= 17.5 \times 6 \times 0.8 \times 270$ $[0.8\, d\, t\, \sigma_{pf}]$

(16mm) - 270

$= 22680 N$

Rivet value, $R_v = 17318.03 N$ (Min.)

Pitch of Rivets $= \frac{2R_v}{F_1}$

$= \frac{2(17318.03)}{168.35} = 205.74 mm$ ≯ 10t

Pitch ≯ 60mm [10t, (10)(6), = 60]

Rivets for horizontal joints are provided at the same pitch as that of vertical joints.

→ Hemispherical bottom plates :-

Hoop stress per unit length in the Radial Joints :-

$$\left[F_2 = \frac{w h D}{4} \right] \quad \left(h = H + \frac{D}{2} \right)$$

$$= \frac{9.81 \times 10^{-6} \times 8.515 \times 10^{3} \times 6.55 \times 10^{3}}{4}$$

$[F_2 = 136.78 \ N/mm]$ → If it's not like this then repeat steps for rivet

Since $F_2 < F_1$. So, Rivets for making connections of hemispherical bottom [illegible]

∴ For Radial as well as horizontal Joints

(IV) [Circular Girder] :-

Weight of water, $[\omega \cdot V]$ → $10\ KN/m^3$ (9.8)

$$W_1 = 10 \times 250 = 2500\ KN \Rightarrow 2500 \times 10^3\ N$$

Self wt. of the Tank :-

$$W_2 = \left[\pi D H t + \frac{1}{2} 4\pi r^2 t\right] \times 7.9 \times 10^{-5}$$

$$= \left[\pi (6.55) 10^3 \times (5.24 \times 10^3) \times 6 + \frac{1}{2} 4\pi (6) \left[\frac{6.55 \times 10^3}{2}\right]^2\right] \times 7.9 \times 10^{-5}$$

(7.9×10^{-5} → unit wt. of steel (79.5 KN/m³))

$$\Rightarrow 83052.77\ N$$

Self wt. of Conical Roof :-

$$W_3 = \frac{\pi D}{2}\left[\sqrt{\left(\frac{D}{2}\right)^2 + \left(\frac{D}{4}\right)^2}\right] \times 6 \times 7.9 \times 10^{-5}$$

$$\Rightarrow 14880.74\ N$$

The self wt. of the Tank & Conical Roof may be increased by 20% to account additional wt. of overlap of plates & connectors.

$$W_4 = 1.2 (W_2 + W_3)$$

$$= 1.2 (83052.77 + 14880.74)$$

[illegible]

Assume self wt. of girder = 1500 N/m

Total self wt. (girder) = $1500 \times (\pi \times 6.55)$ ($\pi \times D$)

= 30866.14 N

Now, Total load on girder :-

$= 2500 \times 10^3 + 117520.21 + 30866.14$

$= [2650 \times 10^3 \text{ KN}]$

For circular girder supported on 8 columns :-

Fixed Formulas

(i) Max. B.M (at supports) $= -0.00827\, WR$, (M)

$= -0.00827 (2650 \times 10^3) \cdot \frac{6.55}{2}$

$= (-71773.26 \text{ N-m})$

(ii) Max. Torsion $= 0.00063\, WR$, (T)

$= 0.00063 (2650 \times 10^3)(6.55/2)$

$= (5467.6 \text{ N-m})$

(iii) Max. S.F $= \frac{W}{16}$, (For 8 columns)

$= \frac{2650 \times 10^3}{16} = (165625.00 \text{ N})$

=

Section Modulus Required :—

$$Z_{req} = \frac{Max\ B.M}{0.66\ f_y} = \frac{M}{f_y}$$

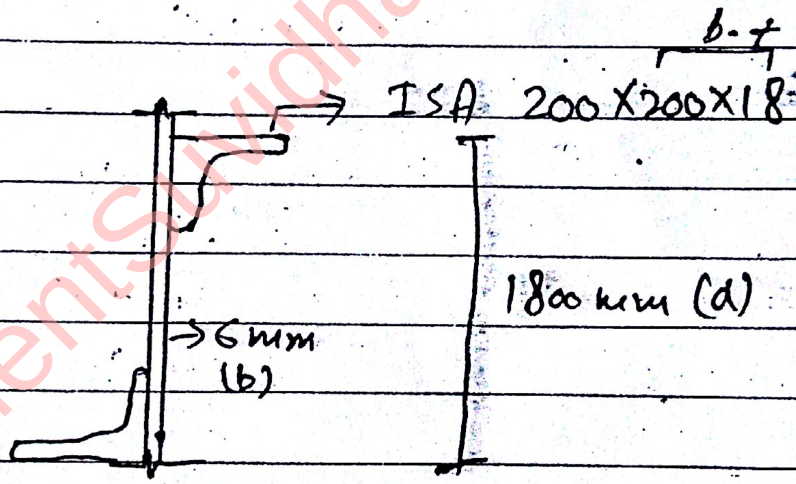
$f_y \rightarrow = 0.6 f_y$

$$= \frac{71773.26 \times 10^3}{0.66\ (250)}$$

$$= (434989.8\ mm^3)$$

Let us try girder section which is built up by using 1.8m depth of cylindrical shell and 2 ISA 200X 200 X18 mm sections.

Choose ISA (equal or unequal angle) from code book, whose $Z > Z_{req}$. If not, then cal. I & Z [If Z_s is not available]



$$I_{xx} = \frac{6 \times 1800^3}{12} + 2 \times 2588.7 \times 10^4$$

$$+ 2 \times 6881 \times (900 - 56.1)^2$$

$$= 1276861.9 \times 10^4\ mm^4$$

$$Z_{prov.} = \frac{1276861.9 \times 10^4}{900} \quad \left(\frac{I}{y}\right)$$

$$= 14187354 > 434989.8\ mm^3$$

$$J = 2\left[\frac{1}{3} bt^3 + (b-t)t^3\right] + \frac{1}{3}d(t)^3$$

Torsion Constant :- $J = \sum \frac{1}{3} bt^3$

$$J = 2\left[\frac{1}{3}(200)(18)^3 + (200-18)18^3\right] + \frac{1}{3}((1800)(6$$

$= 3030048\ mm^4$

Shear stress due to Torsion :-

$$= \left[\frac{T}{J}\ \tau_{max}\right]$$

$$= \frac{5467.6 \times 10^3 \times (18+6)}{3030048}$$

$= (43.30\ MPa)$

Shear stress due to S.F :-

$$= \frac{Max.\ S.F}{2 \times 6881 + 1800 \times 6} \qquad \left[\frac{Max\ S.F}{2a + b.d}\right]$$

$= (6.743\ MPa)$

Total shear Stress :-

$= 43.30 + 6.743$

$S = 50.04\ N/mm^2 < 0.4\ f_y$

$< 100\ N/mm^2$

$\Rightarrow$ (O.K)

$$\left[I_{xx} = \frac{1}{12} bd^3 + 2 I_{yy} + 2 a r^2\right]$$

$a - mm^2$
$I_{yy} - mm^4$
$b = 6,\ d = 18$

and $r = (Y - C_{yy})^2$

Bending stress, σ_{bct} :-

$$= \frac{M}{Z}$$

$$= \frac{71773.26 \times 10^3}{14187354} = 5.059 \text{ MPa}$$

Hoop stress, σ_{at_1} :-

$$= \frac{wHD}{2\eta t}$$

$$= \frac{9.81 \times 10^{-6} (5.24 \times 10^3)(6.55 \times 10^3)}{2(0.75)(6)}$$

$$= 37.41 \text{ MPa}$$

Max. Principal stress :-

$$\sigma_1 = \frac{\sigma_{bct} + \sigma_{at_1}}{2} + \sqrt{\left(\frac{\sigma_{bct} + \sigma_{at_1}}{2}\right)^2 + (S)^2}$$

$$= \frac{37.41 + 5.059}{2} + \sqrt{\left(\frac{(37.41) + (5.059)}{2}\right)^2 + (50.04)^2}$$

$$= 75.59 \text{ MPa} < 0.6 f_y$$

$$< 0.6(250)$$

$$< 165 \text{ MPa}$$

$\Rightarrow$ (O.K)